THE EFFECTS OF GLOBAL WARMING ON THE DISTRIBUTION OF STEELHEAD TROUT POPULATIONS ON THE ALASKA PENINSULA, ALASKA.

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Dewey M. Eaton
and
F. Jeffery Adams

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King Salmon Fishery Resource Office
U.S. Fish and Wildlife Service
P.O. Box 277
King Salmon, Alaska 99613

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ABSTRACT

An investigation to determine the distribution and population characteristics of steelhead trout *Oncorhynchus mykiss* on the Alaska Peninsula, Alaska, was conducted during 1991-1994. It is hypothesized that steelhead trout will extend their range northward and their growth rate will change as a result of increased water temperatures from long-term environmental global warming. The study was the first phase of a long-term investigation initiated in 1991 as part of the global climate change component of the Fishery Resources Status and Trends (FRST). The FRST is designed to assess possible effects of climatic warming on fishery resources.

The six drainages studied were: Meshik River, King Salmon River-Mother Goose Lake, Chignik River, Sandy River, Sapsuk River, and Russell Creek. The Meshik and King Salmon rivers are north of the documented distribution of steelhead on the Alaska Peninsula; the other sites fall within the known range of steelhead trout. Twenty-one adults and 389 juvenile steelhead trout were captured in Russell Creek from 1991-1994. The abundance of juvenile steelhead trout in Second Creek, a tributary to Russell Creek, was estimated at 3,807 ± 1,779 in 1994. Two adult steelhead trout, 40 adult non-anadromous rainbow trout, and 43 juvenile trout were captured in Sandy River from 1992-1993. No steelhead trout were caught in the other four rivers. A total of 753 stream km was surveyed by helicopter in the six study drainages during 1993. One steelhead trout was observed in Russell Creek and 18 redds were observed in Sandy River.

Thermographs were placed in all study drainages and 12-35 continuous months of bi-hourly temperatures were recorded. Minimum temperatures ranged from -0.3 to -2.0 °C. Maximum temperatures ranged from 10.0 to 17.0 °C. Total accumulation of daily temperature units varied from 1,460 in King Salmon River-Mother Goose drainage to 2,067 in Sandy River for a 12 month period common to all drainages.

As expected, steelhead trout were not located in the two northern most drainages. However, no steelhead trout were located in two of the four southern most drainages in which steelhead trout have been previously reported. Alaska Peninsula steelhead populations appear to be small with restricted distributions. Locating these populations is labor and time intensive and overlooking a population is possible. After trying various sampling techniques, methods that maximize the area sampled, such as underwater direct observation and aerial surveys using a helicopter, can be used to document changes in steelhead trout abundance and distribution. The long-term benefit of the sampling program and integration of distribution, abundance, growth, and temperature data will not be realized until additional sampling is conducted in the future.

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INTRODUCTION

In 1991, the U.S. Fish and wildlife Service formed the Fishery Resource Status and Trends Program (FRST) to improve understanding of the status, trends, and causes and effects of changes in fish populations and their habitats. The FRST consists of a fishery inventory component to determine the status and trends of U.S. fishery resources and a climate change component to detect and assess changes in fishery resources and habitats caused by global climate. This study was funded under the climate change component. It was designed as a long-term monitoring program to document changes in the distribution and growth of steelhead trout *Oncorhynchus mykiss* and to correlate changes in distribution and abundance with changes in water temperatures of drainages on the Alaska Peninsula in Southwest Alaska.

This project consists of two phases, the initial phase was a five year study to document the distribution, abundance and growth of steelhead trout and water temperatures of selected drainages. The second phase will be monitoring the same drainages every 2-5 years to document changes in steelhead trout distribution and abundance. This is the final report for the initial study phase.

Steelhead trout in Alaska are found in coastal river drainages in Southeast Alaska, northward and westward around the Gulf of Alaska, and into Southwest Alaska on the Alaska Peninsula (Alaska Department of Fish and Game 1985; Didier et al. 1991). Steelhead trout are most common in the southeast portion of their Alaskan range.

Little information exists on steelhead trout in southwestern Alaska; most information concerning steelhead trout in Alaska comes from Southeast Alaska, northern Gulf of Alaska, Cook Inlet, and Kodiak Island. No directed studies have been conducted in Southwestern Alaska. Information that does exist is incidental or anecdotal and not readily available. Observations of steelhead trout by fishery biologists and recreational, commercial, and subsistence fishermen suggest that steelhead trout occur in several drainages on the Southern portion of the Alaska Peninsula (Irving 1991). However, data from steelhead trout have been collected in few of these drainages (Alaska Department of Fish and Game 1985). No steelhead trout populations are documented on the Alaska Peninsula, north of the Chignik River drainage.

Both spring and fall run steelhead trout populations are found in Alaska. Spring runs are most common in Southeast Alaska, while fall runs are most common in populations North of the Yakutat Peninsula (Alaska Department of Fish and Game 1985). Spawning ages of steelhead trout in Alaska are highly variable (Sanders 1985). Steelhead trout may first spawn after only one winter at sea, however most fish spawn for the first time after two or three winters at sea. The outmigration of kelts in Alaska occurs anytime after spawning with the peak migration occurring before mid-July (Sanders 1985). In Alaska, juveniles spend 1-4 years in freshwater with most fish spending 3 years in freshwater before smoltification (Sanders 1985). In freshwater, juvenile steelhead trout grow to about 100 mm after their first winter and to 150 mm by the end of their second winter (Burgner et al. 1992).

Water temperatures affect the metabolism and behavior of steelhead trout (Shepard 1972; Reiser and Bjornn 1979; Barnhart 1986; Pauley et al. 1986). Effects vary depending on season and life stage. Steelhead trout have evolved within specific water temperature regimes. Significant changes in temperature may cause disease, affect growth and survival, or alter the distribution, migration, and maturation.

It is hypothesized that steelhead trout populations will extend their range northward on the Alaska Peninsula in response to increased water temperatures from long-term global warming. This study provides a baseline for documentation of the presence/absence and abundance of adult and juvenile steelhead trout in selected drainages. Baseline water temperature data were collected to document changes in the thermal regimes of the drainages.

Study objectives are:

(1) Document the presence and abundance of steelhead trout in six selected drainages of the Alaska Peninsula and monitor long term changes in their distribution and abundance.

(2) Describe length, weight, and age structure and sex composition of steelhead trout populations in selected drainages.

(3) Monitor long-term changes in water temperatures and correlate these changes with growth and distribution of steelhead trout on the Alaska Peninsula.

The King Salmon Fishery Resource Office began this study in 1991 (Irving 1991). Sampling in 1992 was an expansion and refinement of field techniques used during 1991 (Adams 1993). Sampling during 1991-1992 focused on ground surveys and resulted in the capture of very few adult or juvenile steelhead trout. The need to cover a large area in each drainage to locate steelhead trout was recognized and an aerial survey was incorporated into the 1993 sampling plan. The aerial survey was used to identify steelhead trout spawning areas. On the ground sampling for juvenile steelhead trout in 1993 was conducted between June and October in systems where adult steelhead trout were captured in 1992. The 1993 sampling concluded that Russell Creek was the only drainage with a readily identifiable steelhead trout population. Therefore, sampling in 1994 focused on Russell Creek in an attempt to determine the abundance of juvenile and adult steelhead trout.

For this report, the term "rainbow trout" refers to non-anadromous adult rainbow trout and the term "steelhead trout" refers to anadromous adult rainbow trout. As juvenile rainbow and steelhead trout are indistinguishable, the term "juvenile trout" refers to both life history forms. All "juvenile trout" in the Russell Creek system are believed to be juvenile steelhead trout.

STUDY AREA

The drainages sampled are located on the Alaska Peninsula in Southwestern Alaska (Figure 1). These systems begin in the mountains of the Aleutian Range and drain into the Bering Sea or Pacific Ocean. The lower reaches of these drainages are subject to tidal influence. The upper reaches of several of the rivers are braided and most of the drainages contain large lakes. Substrate composition includes silt, sand, gravel, and cobble. The riparian habitat is usually tundra with areas of willow *Salix* spp. and alder *Alnus* spp.

METHODS

Distribution, Length, Weight, Age, and Sex Composition

In 1991, six drainages were chosen for ground surveys and water temperature determination (Irving 1991): Meshik River, Chignik River, Sandy River, Sapsuk River, and Russell and Steelhead creeks (Figure 1). Because access to Steelhead Creek was impractical, it was replaced with the King Salmon River-Mother Goose Lake drainage in 1992 (Adams 1993). The Meshik River and King Salmon River-Mother Goose Lake systems were selected because they are north of the documented steelhead range and had not been reported to contain steelhead trout. These two systems will serve as controls and be used to monitor expansion of steelhead range northward.

During 1991-1993, wheel and float-equipped aircraft transported field crews, rafts, and gear into study drainages except Russell Creek. Russell Creek was accessed by road from the town of Cold Bay, Alaska. Sampling on all the drainages began at the highest accessible point. The mainstem of each drainage was sampled throughout its course and the lower reaches of all tributaries were sampled.

During 1991-1992 baited minnow traps, a 15 m beach seine (8 mm bar mesh), and a Smith-Root Model 15-A backpack electrofisher were used to collect juvenile fish in all drainages. In 1992 and 1993, a fyke net (8 mm bar mesh), was used as an additional method to capture juvenile steelhead trout in all drainages except Russell Creek. In 1994, a 10 m bag seine (8 mm bar mesh) and a fyke net (8 mm bar mesh) were used to capture juvenile fish in Russell Creek. A variety of stream habitats were sampled including runs, riffles, pools, root wads, sloughs, and undercut banks; lakes were only sampled along the shoreline. Hook and line was the only sampling method used for adult fish except in Russell Creek where a 50 m beach seine (38 mm bar mesh) was also used.

Because steelhead trout populations on the Alaska Peninsula are small and sporadically distributed, overlooking a population is possible. Therefore, sampling has high variability which makes quantifying relative abundance within reasonable statistical bounds difficult (Adams 1993). To overcome these sampling concerns, the 1993 study design was modified to include an aerial survey during the spring to identify steelhead trout spawning areas. The aerial survey was conducted by helicopter 11-16 May, 1993. The survey was conducted at an altitude of 50-70 m and at a speed of 55-110 km/h. The aerial survey was limited to

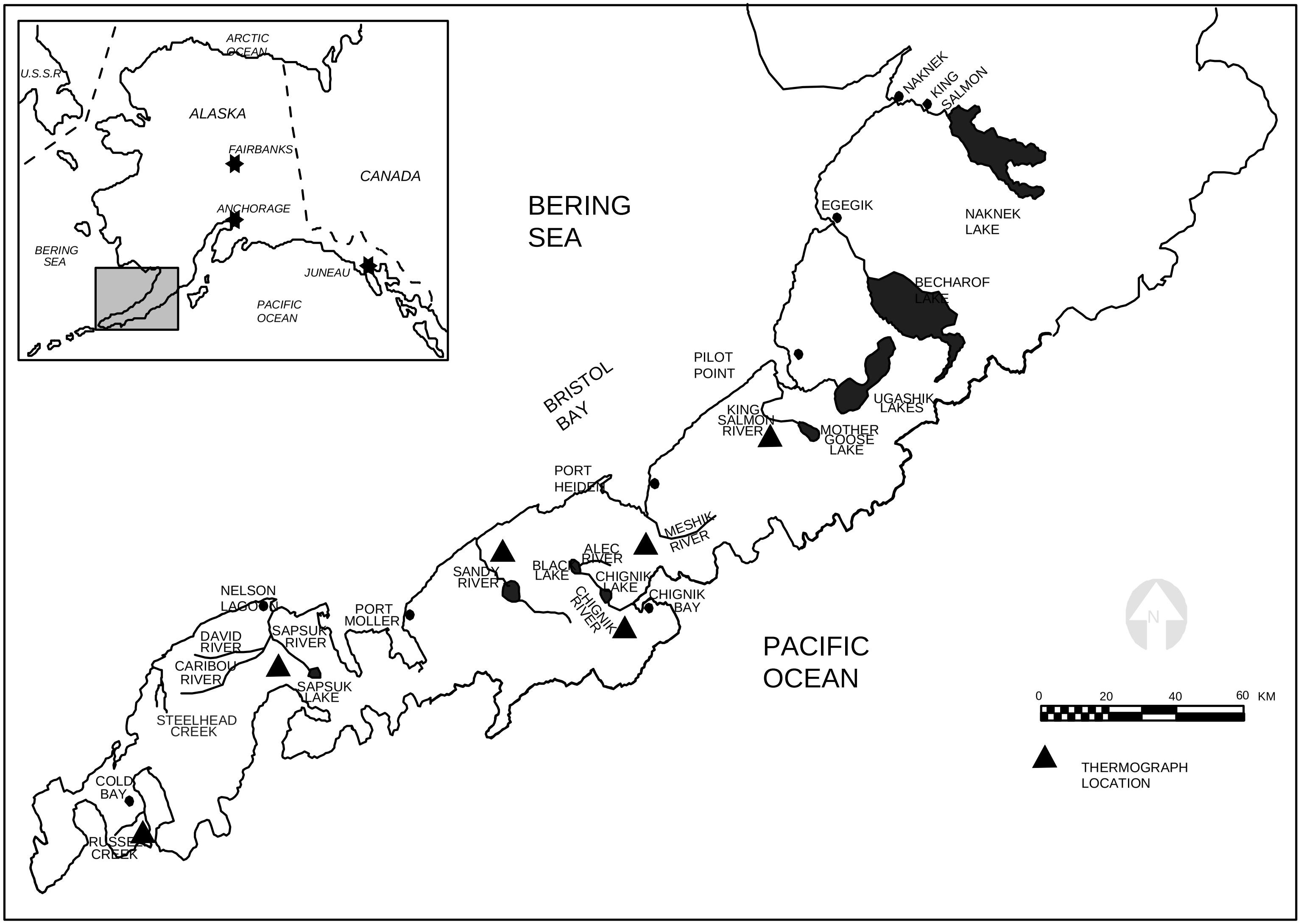

Figure 1.-Location of drainages sampled on the Alaska Peninsula and thermograph locations during 1991-1993.

the areas in the streams where water depth and clarity provided acceptable visibility on the lower portion of the system upstream to where water depth was determined to be too shallow for fish passage. From the air, fish were identified and enumerated, and redd locations were recorded. Species identification was confirmed by hook and line sampling.

All fish captured were enumerated by species. Fork length (mm) was measured from all juvenile trout. Based on ages and fork lengths of juvenile steelhead trout in Russell Creek, those fish < 300 mm captured in Sandy River were considered juveniles. Because adult male steelhead trout undergo morphological changes as they approach spawning, mid-eye to fork length (mm) was measured on all adult steelhead trout. Weights (g) from all adult steelhead trout were measured to the nearest 0.25 kg with a 3 kg or 6 kg Pesola spring scale. Juvenile trout were weighed to the nearest gram with a 50 g Pesola spring scale; however, weight was not recorded for juveniles captured in Russell Creek in 1993 and 1994 due to our inability to accurately weigh small juveniles under field conditions.

During 1991-1993 scales were collected from the preferred area (Jearld 1983) from all steelhead trout. During October 1994, steelhead trout < 70 mm were considered to be age 0. Only a subsample were sampled for age analysis. All captured juvenile steelhead trout > 70 mm were sampled for age analysis. Ages were determined by two readers and disagreements were resolved by conference. Regenerated scales were discarded. Scale analysis followed methods set forth by Mosher (1969). The European method (winters in freshwater.winters in the ocean) was used to designate age for adult fish (Koo 1962). No letter following the saltwater age designated that the fish had not yet spawned in its lifetime. The letter "s" following the saltwater age designated that the fish has survived spawning. A numeral following the "s" represented the number of summers spent in saltwater between spawning runs. For example, 3.2s1s represents an age 6 fish which: 1) spent 3 winters in freshwater before emigration to saltwater; 2) spent 2 summers in saltwater before returning to freshwater to spawn; 3) survived spawning and returned to saltwater; 4) returned to freshwater to spawn again after spending 1 summer at sea. The sex of adult steelhead trout was determined by secondary sex characteristics.

Relative and Absolute Abundance

On the ground sampling in 1993 was directed at juveniles and was conducted only in drainages where adult steelhead trout or redds were observed during the aerial survey. Juvenile sampling was conducted 16-25 June on the Sandy River and 28 August-21 October on Russell Creek. Information on presence and relative abundance of juvenile steelhead trout was used to characterize distribution within the drainages. Additional biological samples were collected from adult steelhead trout during a coho salmon tagging and creel study in Russell Creek.

To provide an index of relative abundance, catch per unit effort (CPUE) for juvenile trout was calculated for each gear type in 1992 and 1993. Units of effort were defined as: minutes shocked for electrofishing, hours fished for hook and line sampling, trap night for minnow traps and fyke nets, and number of hauls for seining. However, with the realization that sample gears used to obtain CPUE required intensive labor and would not provide a statistically valid index of relative abundance, alternative methods were attempted in 1994.

In 1994, sampling was conducted only on Russell Creek from 4-13 May and from 5-17 October. In May, counts of adult steelhead trout and redds from bank and snorkel surveys were made in the mainstem of Russell Creek and Second Creek, a tributary to Russell Creek (Figure 2). Bank surveys were conducted by two people, one on each bank walking downstream and counting all observed adult steelhead trout and redds. Snorkel surveys were conducted with two people working downstream and counting all observed adult steelhead trout and redds in the same area as the bank surveys on the mainstem. Observers were in communication with each other to avoid counting the same fish.

Juvenile sampling in 1994 was conducted only on Second Creek. To avoid disturbing spawning steelhead trout and their redds in the upper portion of Second Creek, sampling for abundance estimation of juvenile trout was deferred to the fall sampling. However, seining was conducted in the lower portion of Second Creek to collect length at age data for juvenile trout. In addition to seining, a fyke net was placed in the mouth of Second Creek to capture emigrating steelhead trout smolts.

In October 1994, sampling was conducted to estimate juvenile steelhead trout abundance on Second Creek from its confluence with Russell Creek upstream to the first lake. Sampling followed Thompson's (1992) double sampling design. The sampled portion of Second Creek was classified as units of riffle, glide or pool habitat type. The length of each habitat unit was measured to the nearest meter with a tape for the entire sample area. A snorkel survey was conducted in systematically selected subsamples of each habitat unit. Removal seining was used to generate abundance estimates from a subsample of the snorkel survey units.

In the snorkel surveys, 1-3 divers moved upstream abreast of each other, counting the number of each fish species. Divers were assigned lanes to prevent double-counting fish. Divers sampled units only once. In units that were selected for removal seining, block nets were set up and the snorkel count was made before seining was done.

The generalized removal model (White et al. 1982) was used to generate an abundance estimate from the removal seining data. Because of the low number of juvenile steelhead trout captured, the combined counts of juvenile Dolly Varden, coho salmon, and steelhead trout captured during removal seining were used to generate an abundance estimate for all juvenile fish. It was assumed that species composition obtained by seining was representative of species composition in the stream. The assumption in using all species to generate a population estimate and in using the seining data to determine species composition is that all species are equally vulnerable to the gear. These data and the abundance estimates for all juvenile fish were used to estimate juvenile steelhead trout abundance within Second Creek.

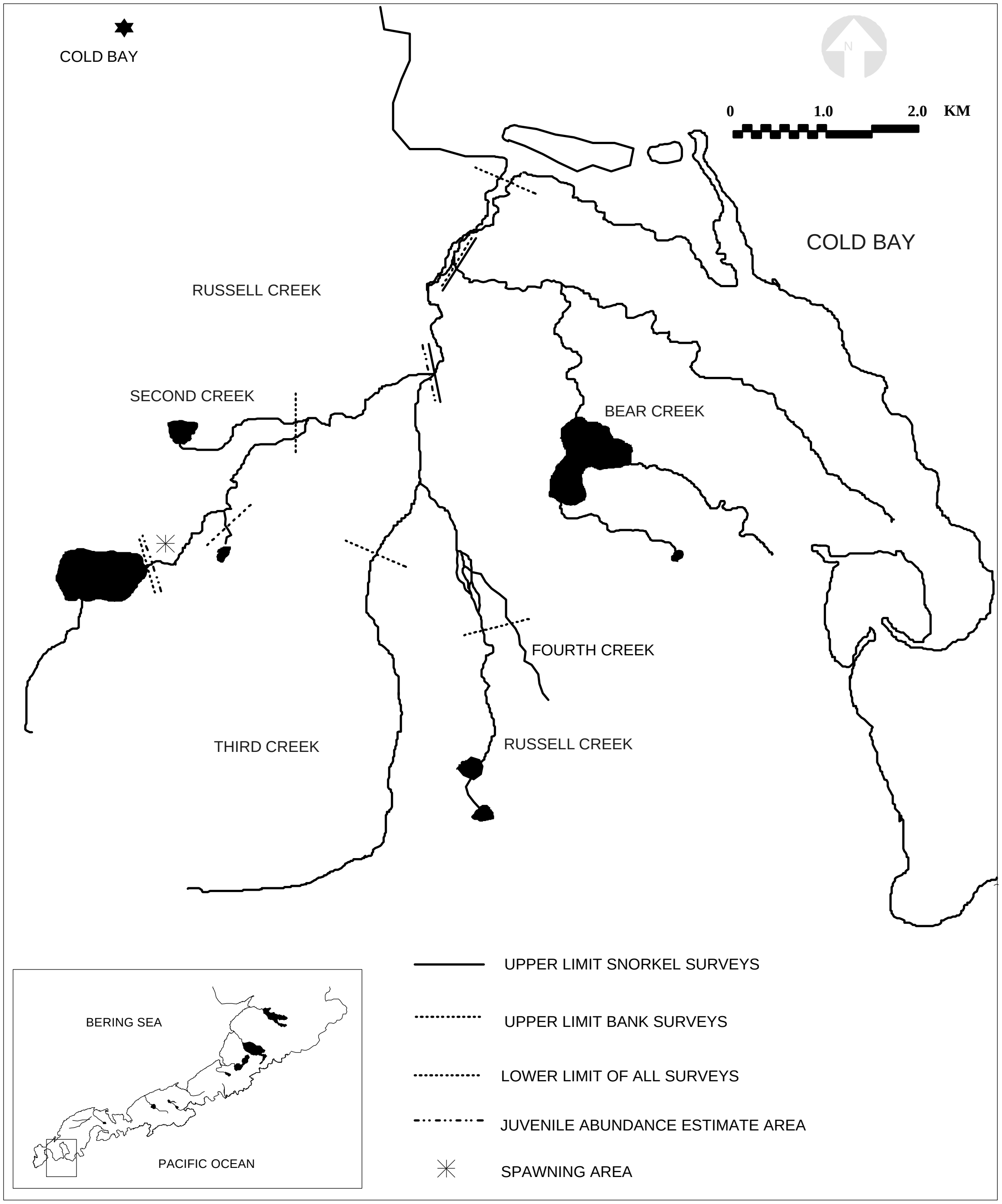

Figure 2.-Upper and lower limits of bank and snorkel surveys and location of spawning area in the Russell Creek drainage.

The total number of juvenile steelhead trout in a habitat type, $\hat{Y}$ was estimated as:

where:

$\hat{Y}_i$ = estimated number of fish in unit *i*
n = number of units in snorkel survey, and
N = the total number of units of a habitat type within the stream.

The number of juvenile steelhead trout in unit *i* was estimated as:

$$\hat{Y}_i = d_i \hat{R} \tag{1}$$

where:

d_i = diver count of number of fish in unit *i*, and
$\hat{R}$ = estimated ratio of fish to diver counts determined by the removal method.

The ratio of fish to diver counts was estimated as:

$$\hat{R} = \frac{\sum_{i=1}^{n'} \hat{y}_i}{\sum_{i=1}^{n'} d_i} \tag{2}$$

where:

$\hat{y}_i$ = removal estimate of number of fish in unit *i*, and
n' = number of units in which snorkel counts and removal estimate were made.

Because the generated removal estimates were for the total number of juvenile fish rather than the total number of juvenile steelhead trout,

$\hat{y}_i$ was estimated as:

$$\hat{y}_i = p_i f_i \tag{3}$$

where:

p_i = number of juvenile steelhead trout expressed as a proportion of the total fish in unit *i*, and
f_i = removal estimate of total number of juvenile fish in unit *i*.

The variance of $\hat{Y}$ was estimated as:

$$\hat{V}(\hat{Y}) = N^2 \frac{\sum_{i=1}^{n} (\hat{Y}_i - \hat{\bar{Y}})^2}{n(n-1)} + \hat{V}(\hat{Y}_R) \tag{4}$$

where:

$$\hat{\bar{Y}} = \frac{\sum_{i=1}^{n} \hat{Y}_i}{n} \tag{5}$$

and

$\hat{V}(\hat{Y}_R)$ = variance about the ratio line.

Equation 5 follows the general formula for multi-stage designs (Cochran 1977, Thompson 1992). The first term contains the within-primary unit variance. The second term contains the conditional variance of the ratio estimate of the total.

The variance of $\hat{Y}_R$ follows that of a ratio estimate of a total (Cochran 1977) and was estimated as:

$$\hat{V}(\hat{Y}_R) = \hat{V}(\hat{y}) - 2\hat{R}c\hat{o}v(\hat{y}\hat{d}) + \hat{R}^2\hat{V}(\hat{d}) \tag{6}$$

$$\hat{V}(\hat{y}) = N^2 \frac{\sum_{i=1}^{n'} (\hat{y}_i - \hat{\bar{y}})^2}{n'(n'-1)} + N \frac{\sum_{i=1}^{n'} \hat{V}(\hat{y}_i)}{n'}, \tag{7}$$

$$c\hat{o}v(\hat{y}\hat{d}) = N^2 \frac{\sum_{i=1}^{n'} (\hat{y}_i - \hat{\bar{y}})(\hat{d}_i - \hat{\bar{d}})}{n'(n'-1)}, \tag{8}$$

where:

$$\hat{\bar{d}} = \frac{\sum_{i=1}^{n'} \hat{y}_i}{n'}, \tag{9}$$

and

$$\hat{V}(\hat{d}) = N^2 \frac{\sum_{i=1}^{n'} (\hat{d}_i - \hat{\bar{d}})^2}{n'(n'-1)}. \quad \textbf{(10)}$$

In equation 8, the variance follows that of a two stage design similar to that in equation 5. The first term contains the between-unit-variance for $\hat{y}$ and the number of fish per unit determined by the removal method. The second term contains the within-unit variance. The within-unit variance is composed of two parts, the first comes from the variance associated with the removal estimate itself and the second comes from the variance associated with estimating the proportion that each fish species contributed to the total removed by seining. The variance of $\hat{y}$ was based on Goodman's (1960) result for the variance of the product of two independent variables and was calculated as:

$$\hat{V}(\hat{y}_i) = \hat{p}_i^2 \hat{V}(\hat{f}_i) + \hat{f}^2 \hat{V}(\hat{p}_i) - \hat{V}(\hat{f}_i)\hat{V}(\hat{p}_i) \quad \textbf{(11)}$$

where:

$\hat{V}(\hat{f}_i)$ = variance from the removal estimate for unit *i*, and

$$\hat{V}(\hat{p}_i) = \frac{p(1-p)}{n'-1}. \quad \textbf{(12)}$$

Water Temperature

During 1991-1993, water temperature (°C) was recorded with Ryan Tempmentor Model 1.1 thermographs every two hours. Thermographs were housed in a steel pipe container, placed in a deep, non-tidal stream area, and anchored to the substrate. Thermographs were placed in the Meshik, Chignik, Sandy, Sapsuk, and Russell Creek drainages in October and November 1991. In June 1992, a thermograph was placed in the King Salmon River-Mother Goose Lake drainage. Temperature data were retrieved in July and August 1992 and the thermographs were reset. Lost thermographs were replaced. While five of the thermographs and their data were retrieved in November 1993, the thermograph at Russell Creek was reset after its data were retrieved. When reset, the thermograph was reprogrammed to record water temperature every four hours to extend battery life. Temperature data were retrieved again in October 1994 and the thermograph reset. The Russell Creek thermograph will continue to be operated for the duration of the global climate change project.

Temperature data were analyzed to develop mean daily temperature and accumulated daily temperature units (the mean water temperature above 0 °C for a 24 hour period - DTU). Mean daily temperature was based on the readings over a 24 hour period from midnight to midnight. To allow comparisons of water temperature between drainages, DTUs were summed for each month in each drainage and for the 12 month period common to all drainages.

RESULTS

Distribution, Length, Weight, Age, and Sex Composition

Four-hundred-ten steelhead trout were captured in Russell Creek (Table 1). All juveniles were captured in Second Creek (Figure 2) except the one juvenile captured in 1991 in the mainstem of Russell Creek. Few juvenile trout were captured in 1991 and 1992. In 1993 and 1994, 116 and 271 juvenile trout were captured. Age 0 fish dominated samples in 1993 and 1994. Juvenile fork lengths (N = 389) ranged from 38-300 mm and ages ranged from 0-4 years.

No adult steelhead trout were captured in Russell Creek in 1991. Nine adults were captured by beach seine during a coho salmon study in 1992 and 1993. During the aerial survey in 1993, one adult was captured by angling. Eleven adults were captured with a fyke net in 1994. Fork length of all adults ranged from 497-785 mm, weights ranged from 2,400-4,700 g, and ages ranged from 2.3-3.3s1 (Table 1).

The majority of adults from Russell Creek spent three years in fresh water before smoltification. Seven adults had not spawned after returning to freshwater, nine had spawned for the first time, and five were repeat spawners. Only the 11 adult steelhead trout captured in May 1994 expressed secondary sexual characteristics and appeared to have recently spawned. Eight of these adults were male and 3 were female.

Eighty-five rainbow and steelhead trout were captured in the Sandy River (Table 2). Juvenile lengths (N = 43) ranged from 49-295 mm; weights from 1-300 g; and ages from 0-3 years. Age 1 fish dominated the 1992 sample, while age 1-4 fish were equally present in the 1993 sample. The majority of juveniles (90%) were captured in the middle region of Sandy River.

Two adults steelhead trout and 40 rainbow trout were captured in the Sandy River in 1992 and 1993 (Table 2). Adult steelhead trout fork lengths ranged from 540-570 mm and weights from 2,450-3,600 g. Rainbow trout fork lengths ranged from 340-535 mm, weights ranged from 350-1,400 g, and ages ranged from 4-6 years.

The two steelhead trout from the Sandy River drainage expressed secondary sex characteristics. Both fish were darkly colored males with well developed kypes, had firmly embedded scales, and appeared to have spawned earlier in the year (Adams 1993).

Relative and Absolute Abundance

Catch rates were low for all gear types in the Sandy River and Russell Creek drainages in 1992 and 1993 (Table 3). Seining had the highest CPUE in Russell Creek at 0.96 juvenile trout/haul, while in the Sandy River no juvenile trout were captured by seining. In the Sandy River,

Table 1. Sample size, mean, standard deviation, and range of lengths (mm) and weights (g) at age of steelhead trout captured in Russell Creek drainage, 1991-1994.

	Length[a]				Weight			
Age	*N*	$\overline{X}$	SD	Range	*N*	$\overline{X}$	SD	Range
				SEPTEMBER 1991				
1	1	89.0	-	-	1	7.0	-	-
				SEPTEMBER-OCTOBER 1992				
1	1	68.0	-	-	1	4.0	-	-
2.3	2	593.5	11.5	582-605	2	2,575.0	25.0	2,550-2,600
3.2	2	614.5	2.5	612-617	2	3,250.0	150.0	3,100-3,400
3.3s1	1	680.0	-	-	1	3,800.0	-	-
				AUGUST-OCTOBER 1993				
0	95	50.4	4.9	39-65	-	-	-	-
1	16	74.9	10.8	55-95	-	-	-	-
2	3	113.7	0.5	113-114	-	-	-	-
3.2	3	636.3	56.8	565-704	3	3,666.7	792.0	2,550-4,300
3.3s	1	672.0	-	-	1	2,400.0	-	-
3.3s1	1	694.0	-	-	1	4,700.0	-	-
unk[b]	2	92.0	3.0	89-95	-	-	-	-
				MAY 1994				
1	19	58.0	5.0	48-66	-	-	-	-
2	16	86.0	11.7	71-117	-	-	-	-
3	16	154.0	13.8	124-175	-	-	-	-
4	3	259.0	34.8	215-300	-	-	-	-
3.2s	3	597.0	71.0	497-650	-	-	-	-
3.3s	5	667.0	66.4	580-785	-	-	-	-
3.3s1s	2	683.0	62.5	620-745	-	-	-	-
unk[b]	2	495.0	250.0	245-745	-	-	-	-
				OCTOBER 1994				
0	7	59.0	5.8	47-64	-	-	-	-
0[c]	199	51.0	5.1	38-66	-	-	-	-
1	7	85.0	3.8	81-93	-	-	-	-
2	3	149.0	6.0	141-155	-	-	-	-

[a] Measured as fork length for juveniles and mid-eye to fork length for adults

[b] Scales unreadable and ages could not be determined.

[c] Age samples were not collected, but fish were considered to be age 0 based on 1993 data.

Table 2. Sample size, mean, standard deviation, and range of lengths (mm) and weights (g) at age for rainbow and steelhead trout captured in the Sandy River drainage, 1992-1993.

	Length[a]				Weight			
Age	*N*	$\overline{X}$	SD	Range	*N*	$\overline{X}$	SD	Range
				JULY 1992				
0	1	49.0	-	-	1	1.0	-	-
1	18	86.8	10.5	70-107	16	8.1	2.5	4-12
2	4	154.5	3.0	150-158	4	41.5	4.8	35-49
4	1	328.0	-	-	1	350.0	-	-
5	3	446.3	14.4	430-465	3	1,133.3	102.7	1,000-1,250
2.2s	2	555.0	15.0	540-570	2	3,025.0	575.0	2,450-3,600
				JUNE 1993				
1	7	86.1	14.3	66-113	7	6.6	3.0	3-12
2	7	152.4	27.7	125-205	7	42.4	24.4	23-93
3	6	264.8	17.8	240-295	6	206.3	57.0	128-300
4	7	381.4	34.5	340-458	7	653.6	135.2	525-875
5	17	438.0	27.7	373-485	17	898.5	181.0	525-1,200
6	8	497.3	28.3	455-535	7	1206.3	168.1	950-1,400
Unk[b]	4	443.5	35.4	407-502	4	900.0	103.1	775-1,025

[a] Measured as fork length for juveniles and mid-eye to fork length for adults

[b] Scales unreadable and ages could not be determined.

Table 3. Gear type, amount of effort (E), number of juvenile steelhead trout captured, catch per unit effort (X), standard deviation, and range of number of juvenile steelhead trout captured per effort in Russell Creek and Sandy River drainages, 1992-1993.

	1992					1993				
Method	E	N	$\bar{X}$	SD	Range	E	N	$\bar{X}$	SD	Range
<u>RUSSELL CREEK</u>										
Electrofisher	255	1	<0.01	-	-	12	4	0.33	-	-
Fyke net	6	0	0	0	0	0	0	0	0	0
Minnow trap	29	0	0	-	-	84	31	0.37	-	-
Seine	5	0	0	0	0	84	81	0.96	3.11	0-20
Hook and line	25	0	0	-	-	0	0	0	-	-
<u>SANDY RIVER</u>										
Electrofisher	280	16	0.06	-	-	295	4	0.01	-	-
Fyke net	5	3	0.60	0.80	0-2	4	2	0.50	0.50	0-1
Minnow trap	28	4	0.14	-	-	0	0	0	-	-
Seine	18	0	0	0	0	34	0	0	0	0
Hook and line	23	0	0	-	-	53	14	0.26	-	-

- Information not available due to pooling of capture data

CPUE was similar between years for electrofishing and fyke nets, but was higher in 1993 for hook and line sampling.

Aerial surveys covered 753 km in six drainages (Figures 3-8), but evidence of steelhead trout spawning activity (redds) was observed in only the Sandy River drainage (Table 4). Eighteen redds were observed in two locations in the Sandy River, but no steelhead trout were seen near the redds. However, two adult rainbow trout were captured from a deep pool downstream from the redds. One adult steelhead trout was observed in the Russell Creek drainage during the aerial survey, but was not captured. However, one adult steelhead trout was captured and three others were hooked but lost while sampling deep pools. No fish had been observed in the pools from the air.

Second Creek was classified into 123 riffle and 156 glide habitat units. Total length of each habitat type was 2,381 m of riffle habitat and 2,284 m of glide habitat. No pool type units were found within the study area. Snorkel counts were made in 20 riffle units and 26 glide units representing 16% and 19% of the total length of each respective habitat type. Removal seining was conducted in 4 units of each habitat type. Mean number of seining passes per unit was 8 for riffles (range 5-10) and 6 for glides (range 5-7).

Agreement between snorkel counts and removal estimates of abundance was better in glide units than in riffle units. Correction factors of 1.18 (glides) and 0.67 (riffles) where estimated and used to adjust snorkel counts. There was a large difference in juvenile trout abundance between habitat types, with nearly 6.5 times more juvenile trout in glide habitat than in riffle habitat. Estimated total abundance of juvenile steelhead trout in all glides was 3,329 fish (SE = 729.5 and 95% confidence = ± 1,430 fish) and 478 fish (SE = 178.1 and 95% confidence = ± 349 fish) in riffles.

Counts of adult steelhead trout and redds were higher in Second Creek than the mainstem of Russell Creek during bank surveys conducted in May, 1994. Eighteen adult steelhead trout observed in Second Creek and twelve redds were observed within a 300 m area of Second Creek (Figure 2). Three adult steelhead trout were observed in the mainstem of Russell Creek below the confluence of Second Creek. No redds were observed in the mainstem of Russell Creek.

Water Temperature

From fall 1991 through fall 1993, bi-hourly water temperature data were recovered from the Chignik River, Sapsuk River, and Russell Creek thermographs sites (Figure 9). An additional year (fall 1993-fall 1994) of water temperature data were recovered from Russell Creek. The original thermographs deployed in the Meshik and Sandy River drainages were never recovered. The replacement thermographs provided 17 and 12 months of continuous bi-hourly temperature readings for these drainages respectively and the additional thermograph placed in King Salmon-Mother Goose Lake system provided 17 months of continuous bi-hourly temperature data (Figure 10). Maximum mean daily water temperature occurred during July or August and ranged from 10.3 °C in King Salmon River-Mother Goose Lake to 16.3 °C in Sandy River. The minimum mean daily water

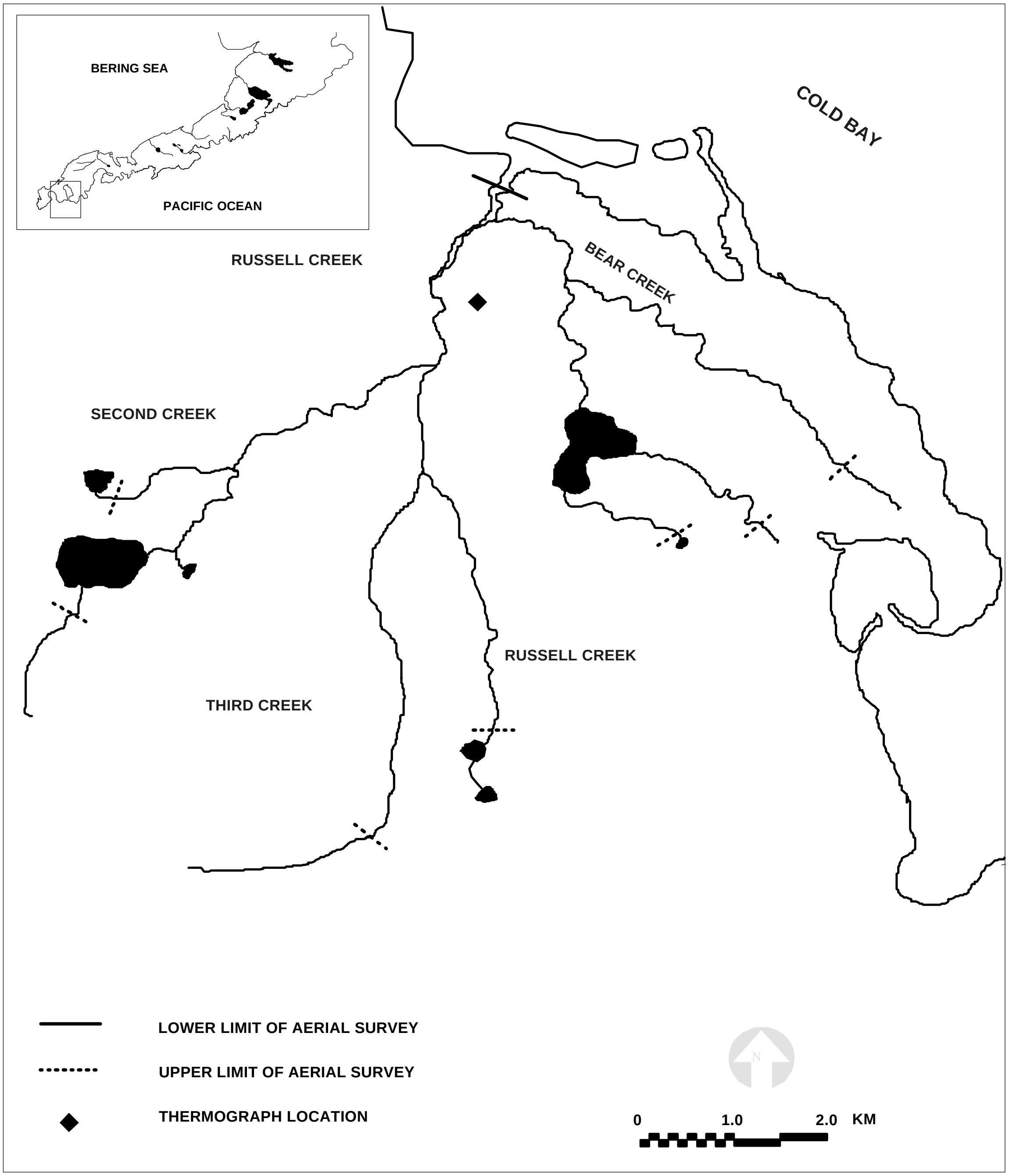

Figure 3.-Access locations, thermograph placement, and upper and lower limits of the aerial surveys in the Russell Creek drainage.

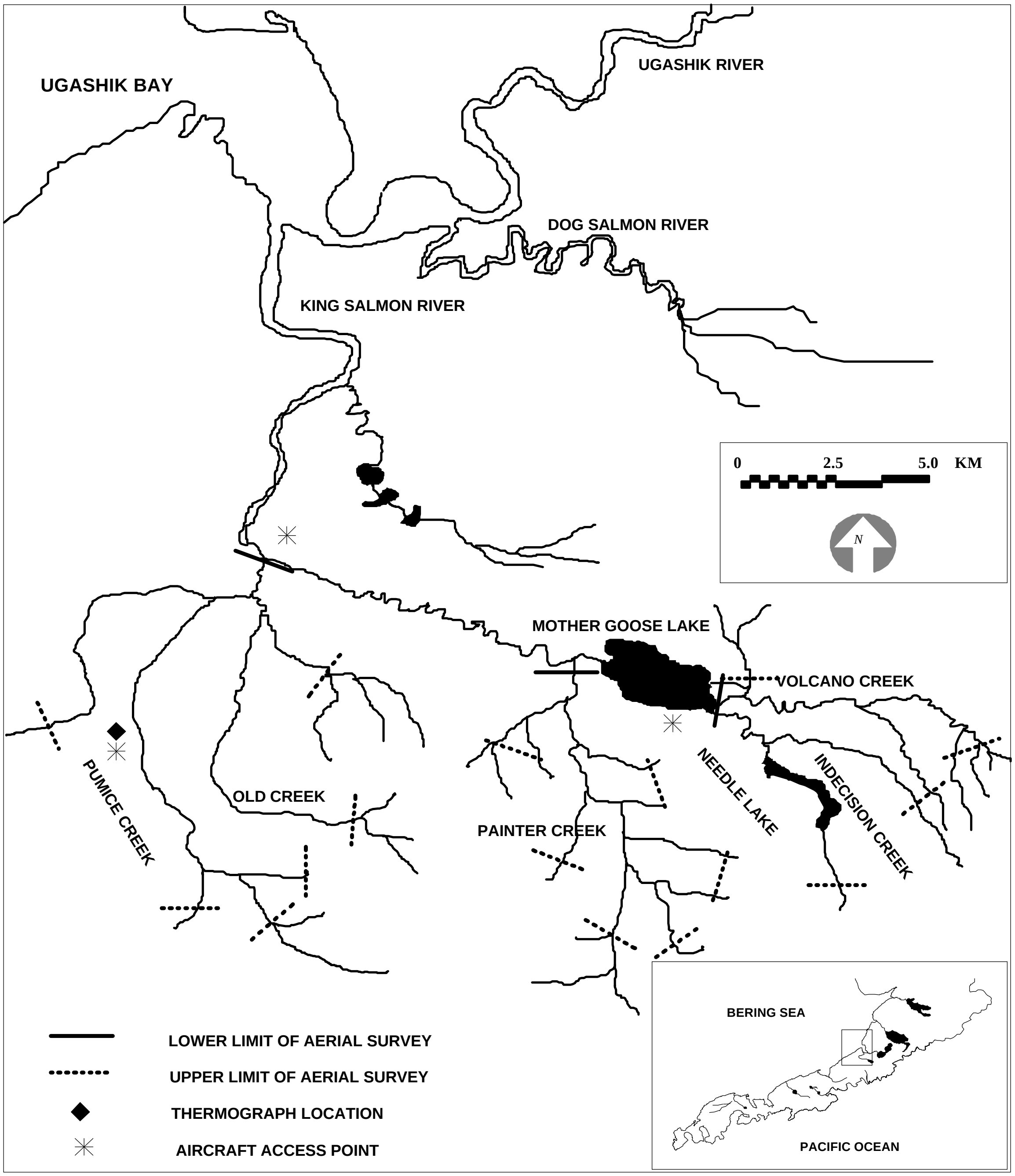

Figure 4.-Access locations, thermograph placement, and upper and lower limits of the aerial surveys in the King Salmon River-Mother Goose Lake drainage.

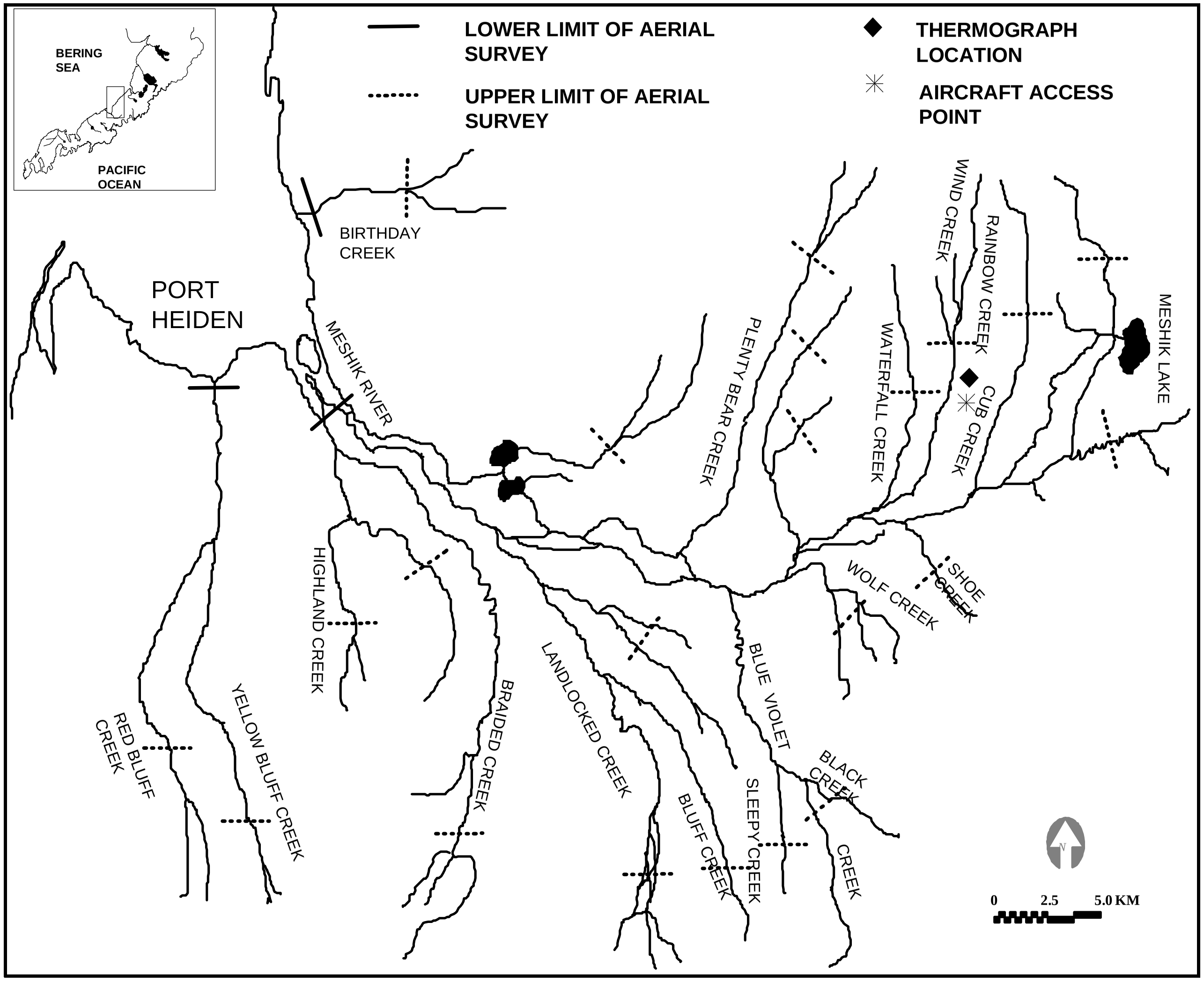

Figure 5.-Access locations, thermograph placement, and upper and lower limits of the aerial surveys in the Meshik River drainage

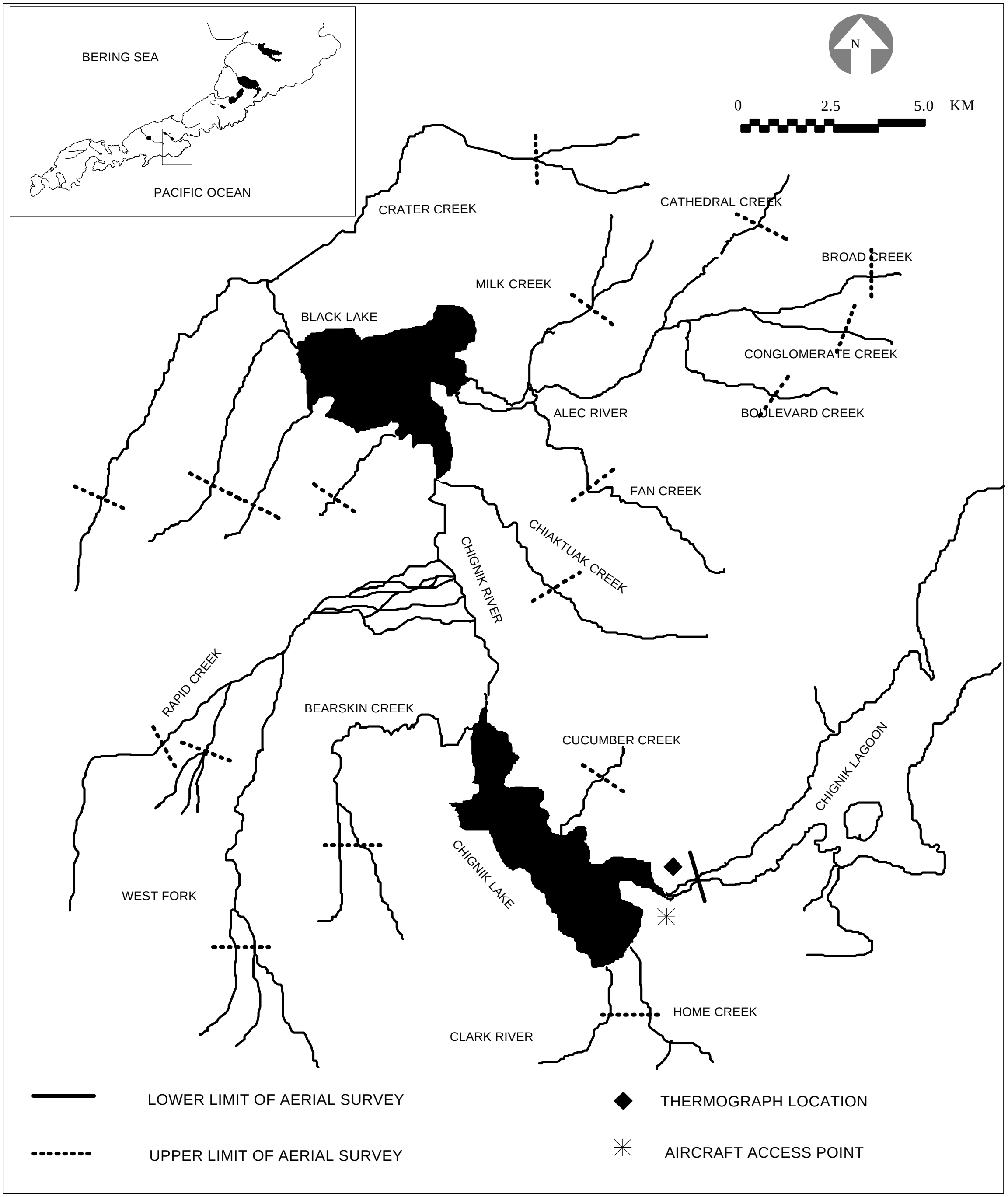

Figure 6.-Access locations, thermograph placement, and upper and lower limits of the aerial surveys in the Chignik River drainage

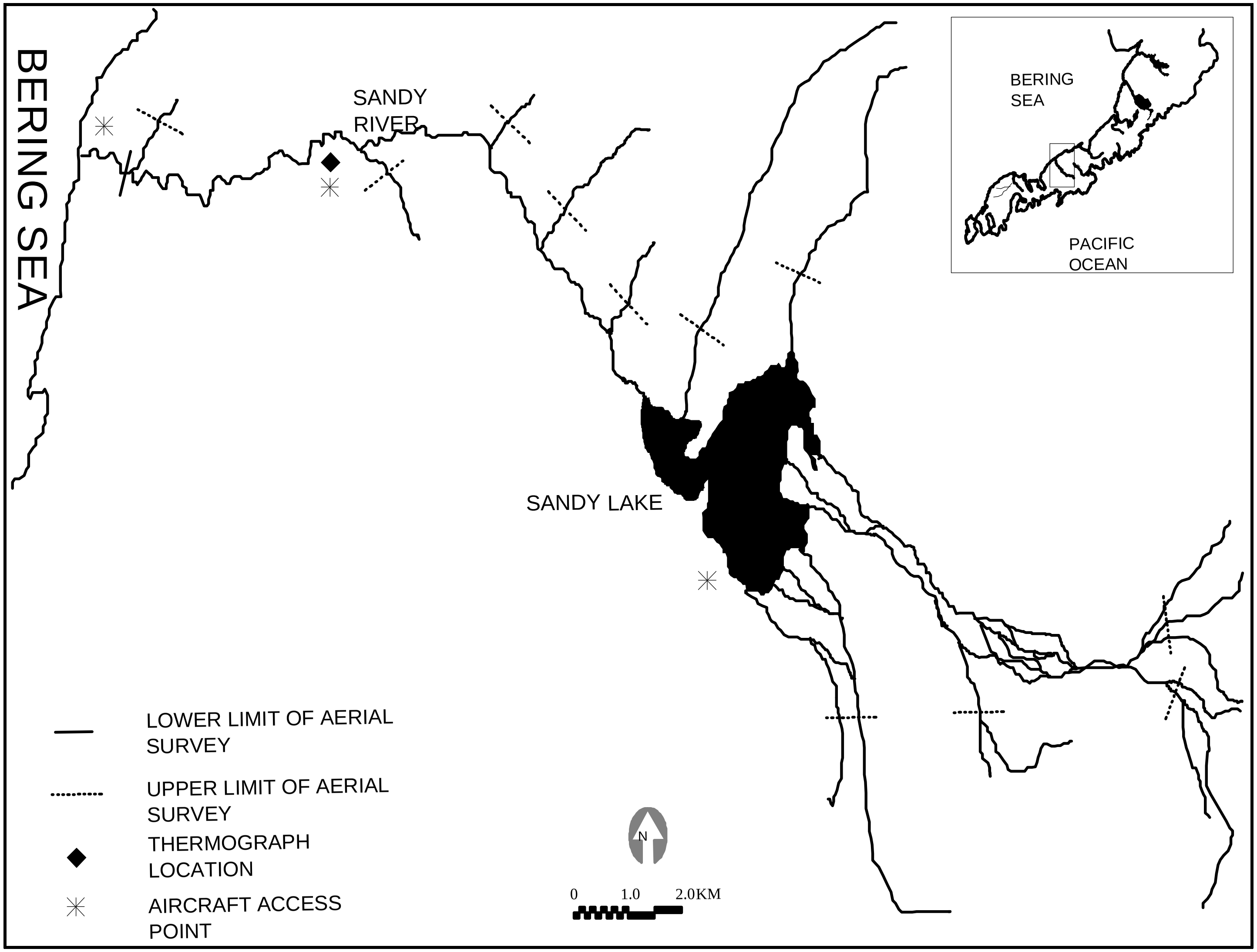

Figure 7.-Access locations, thermograph placement, and upper and lower limits of the aerial surveys in the Sandy River drainage.

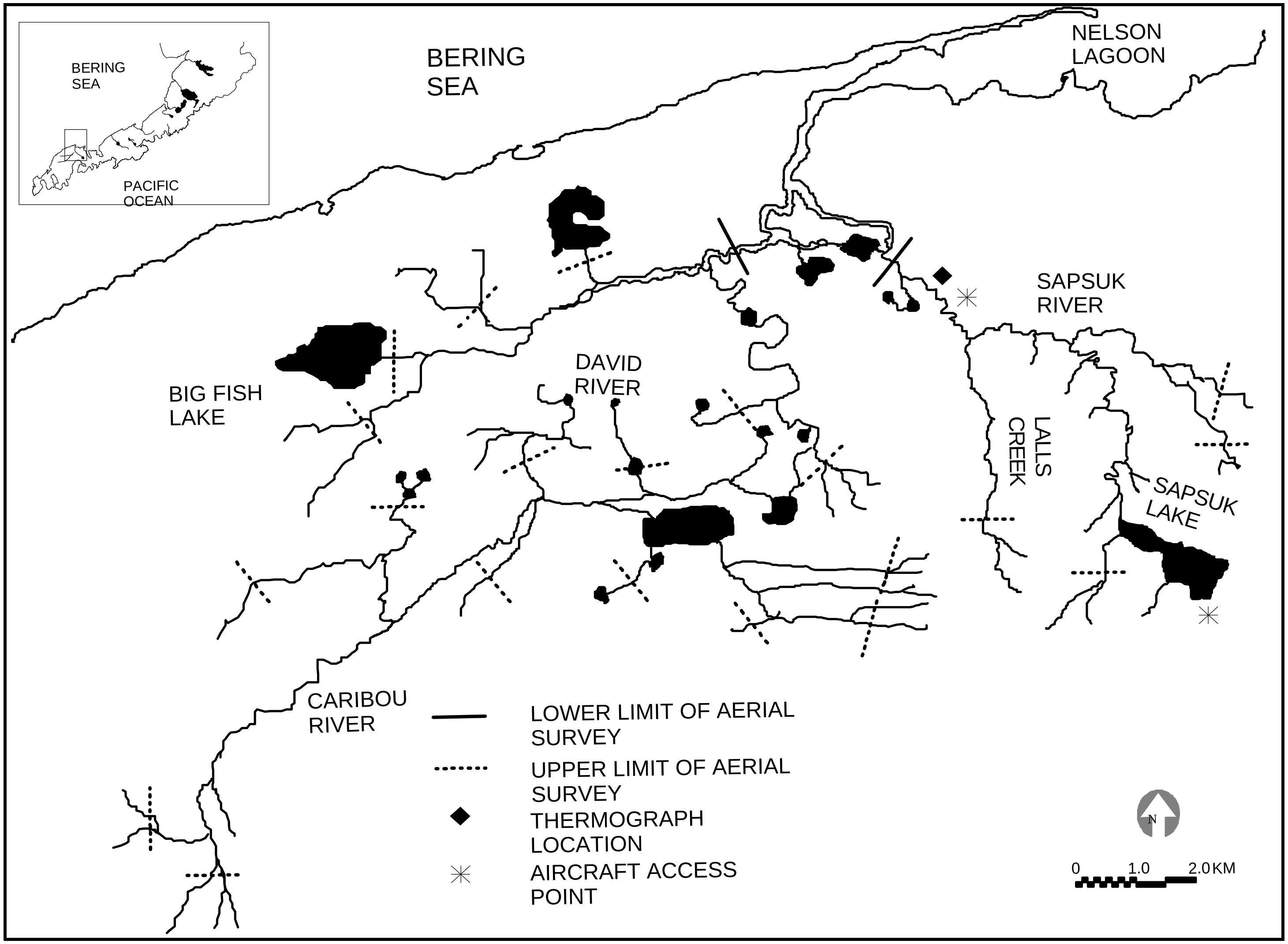

Figure 8.-Access locations, thermograph placement, and upper and lower limits of the aerial surveys in the Sapsuk River drainage.

Table 4. Distance surveyed and number of steelhead trout and redds observed during the aerial survey in May 1993.

Drainage	Date	Kilometers Surveyed	Number Fish Observed	Number Redds Observed
King Salmon River-Mother Goose Lake	May 11	125	0	0
Meshik River	May 11-12	195	0	0
Chignik River	May 12-13	118	0	0
Sandy River	May 13-14	105	0	18
Sapsuk River	May 14-15	178	0	0
Russell Creek	May 16	32	1	0

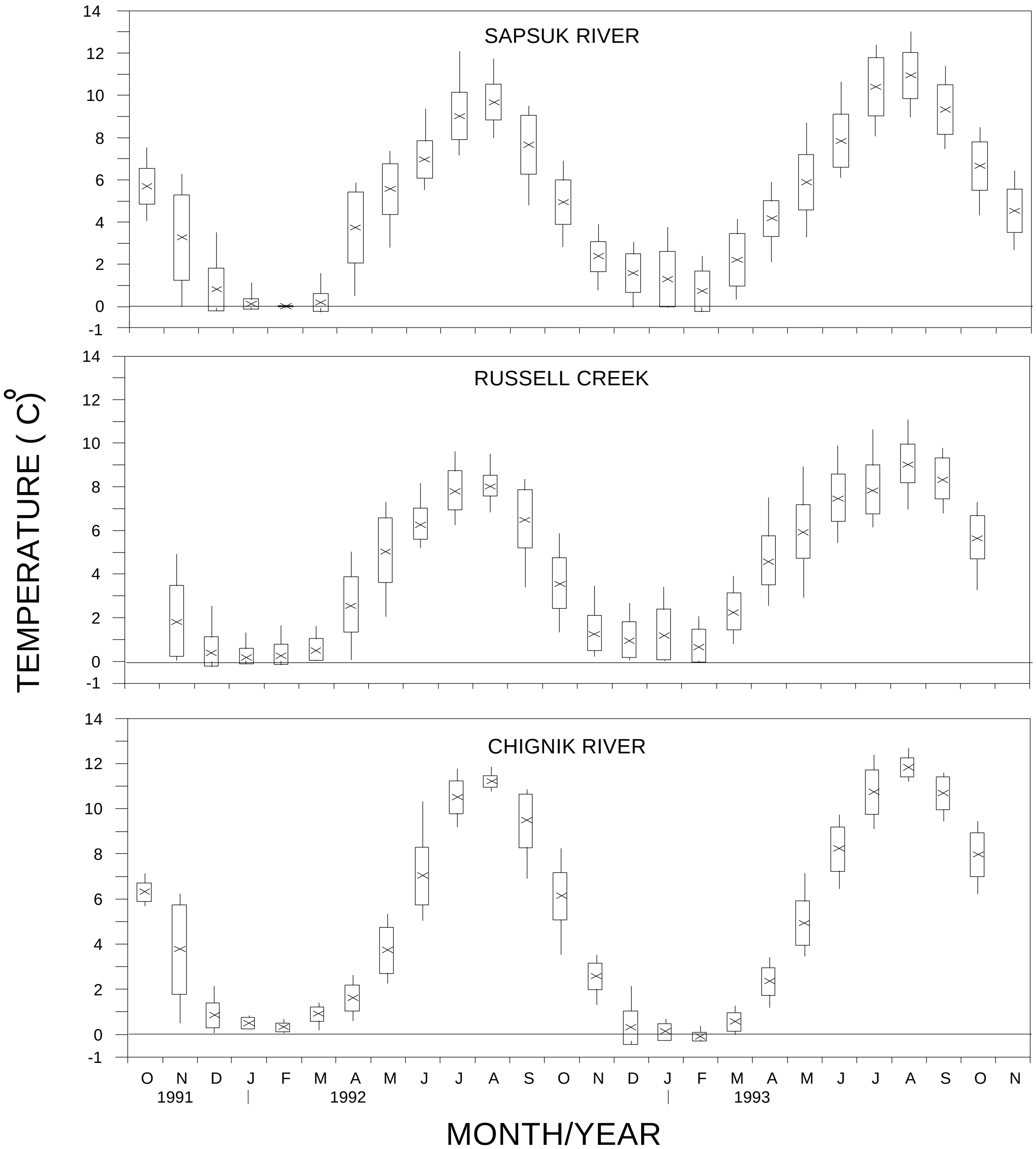

Figure 9.-Mean, standard deviation, and minimum and maximum monthly temperatures from the Sapsuk River, Russell Creek, and Chignik River.

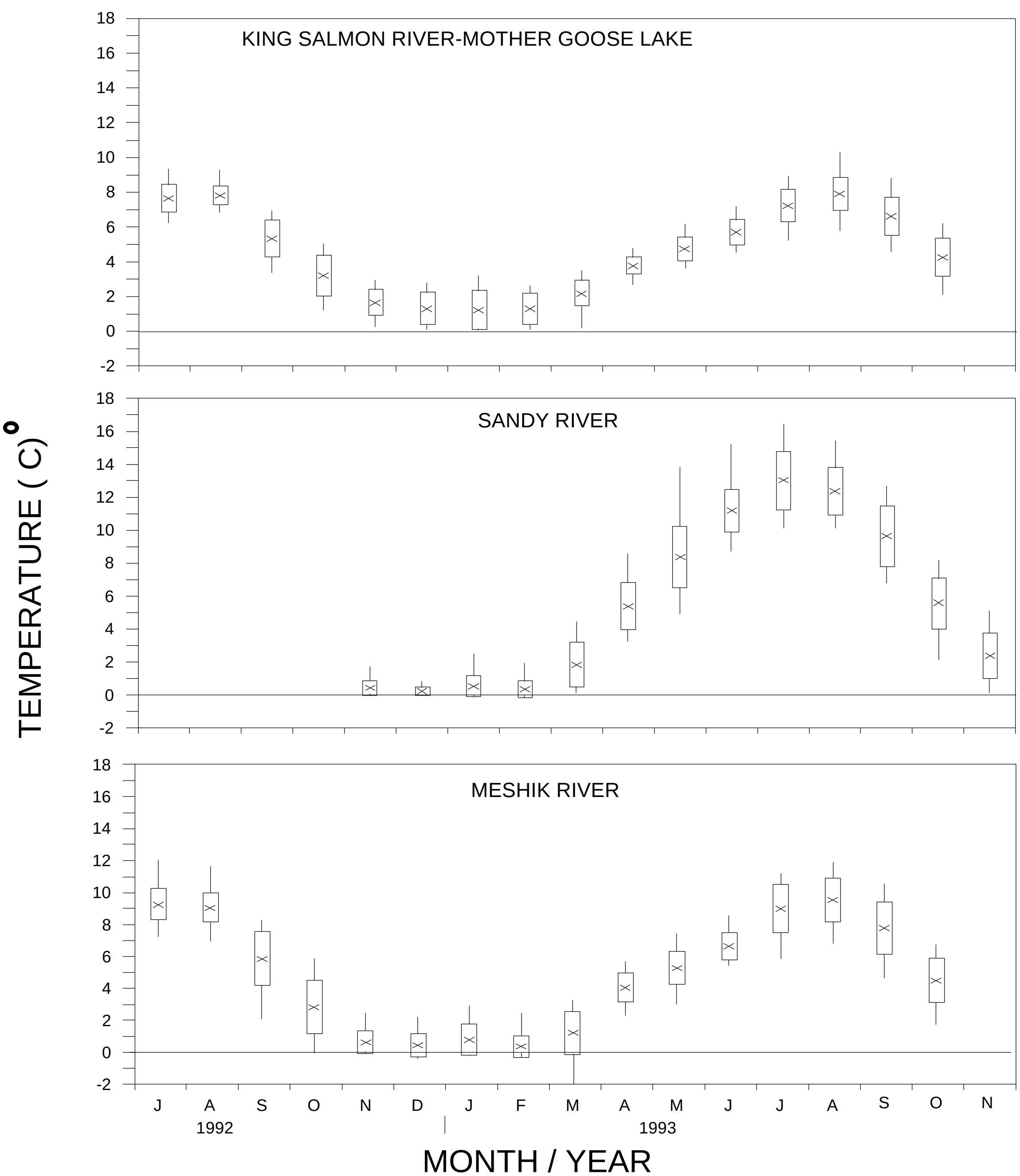

Figure 10.-Mean, standard deviation, and minimum and maximum monthly temperatures from the Meshik River, Sandy River, and King Salmon River-Mother Goose Lake drainage.

temperature occurred during November through February and ranged from -0.3 °C in Sapsuk River to -2.0 °C in Meshik River. Monthly DTU ranged from 0.7 in Sapsuk River in February 1992 to 400.8 in Sandy River in July 1993 (Table 5). Total accumulated DTU ranged from 1,460 on the King Salmon-Mother Goose Lake system to 2,067 on the Sandy River for the period common to all drainages (Figure 11).

Nearly three consecutive years of water temperature data from Russell Creek indicated that the monthly mean water temperature was relatively consistent between years (Figure 12). Mean monthly temperature varied more than 10 °C from winter to summer. The range between minimum and maximum temperatures within a month rarely exceeded 5 °C.

DISCUSSION

Distribution

As expected, no steelhead trout were captured or observed in the Meshik River and the King Salmon River-Mother Goose Lake drainages. Wagner and Lanigan (1988) also did not capture steelhead trout during their study of the Meshik River during the summer of 1984. These systems are north of the documented range of steelhead trout on the Alaska Peninsula and will be used to detect any northward range expansion of steelhead trout on the Alaska Peninsula.

Steelhead trout were expected to be captured in the remaining drainages. However, no steelhead trout were captured or observed in the Chignik River and Sapsuk River drainages. Steelhead trout have been reported in the Chignik River system, but their abundance appears to be low. Kelts (emigrating post spawners) have been observed during their outmigration at the Alaska Department of Fish and Game sockeye salmon weir on the Chignik River (Allen Quimby, Alaska Department of Fish and Game, personal communication). Kelts have also been captured in gill nets during the sockeye salmon subsistence fishery. During directed sampling in 1991-1992 and during the aerial survey in May 1993, no steelhead trout were captured or observed in the Chignik River. In addition, the Fishery Research Institute of the University of Washington has been sampling sockeye salmon populations throughout the Chignik River drainage since 1955 without capturing any steelhead trout (Gregory Ruggerone, University of Washington, Seattle, personal communication). Anecdotal information from local residents suggests that the Alec (Scow) River may be the major spawning tributary for steelhead trout in the drainage, but, this tributary was not sampled because access was difficult.

Although steelhead trout were not captured in 1992 or observed during the aerial surveys in 1993 in the Sapsuk River drainage, commercial fishermen have reported capturing kelts during the sockeye salmon fishery in the lower reaches of the drainage (Bob Berceli, Alaska Department of Fish and Game, personal communication). Kelts have not been observed during their outmigration at the Alaska Department of Fish and Game sockeye salmon weir on the Sapsuk River mainstem. Local residents and sport fishermen have reported catching steelhead trout in the Caribou-David River system. This system may provide the major

Table 5. Monthly accumulated daily temperature units for drainages sampled during 1991-1993.

Date	Chignik River	Russell Creek	Sapsuk River	King Salmon-Mother Goose	Sandy River	Meshik River
1991						
November	113.8		98.5		-[a]	-[a]
December	26.8	12.5	25.9		-	-
1992						
January	16.1	6.2	4.4		-	-
February	9.8	8.0	0.7		-	-
March	28.8	15.4	6.3		-	-
April	49.0	76.5	112.7		-	-
May	116.4	156.3	172.8		-	-
June	211.4	187.4	209.3		-	-
July	326.2	241.5	280.0	237.5	-	286.7
August	348.0	248.0	300.5	241.9	-	280.2
September	285.0	194.4	230.2	159.8	-	175.2
October	190.4	109.6	153.6	99.4	-	87.8
November	77.7	37.6	71.6	49.2	10.5	19.3
December	12.5	29.0	49.3	40.3	4.6	15.3
TOTAL	1617.3	1309.9	1591.4	828.1	15.1	864.5
1993						
January	7.4	36.4	40.3	37.8	13.9	25.6
February	1.5	18.2	20.8	35.2	7.6	10.1
March	18.1	69.7	68.9	68.2	49.7	42.0
April	71.0	137.4	125.2	113.2	153.6	121.6
May	153.4	182.6	182.7	146.6	256.8	163.4
June	247.3	223.5	235.3	170.8	332.8	199.4
July	333.4	242.6	323.0	223.9	400.8	278.8
August	367.2	279.7	339.6	244.9	380.0	295.5
September	321.2	247.9	280.2	198.4	286.3	233.2
October	247.2	170.6	206.8	132.2	170.6	139.1
TOTAL	1767.7	1608.6	1822.8	1371.2	2052.1	1508.7

[a] Thermograph lost

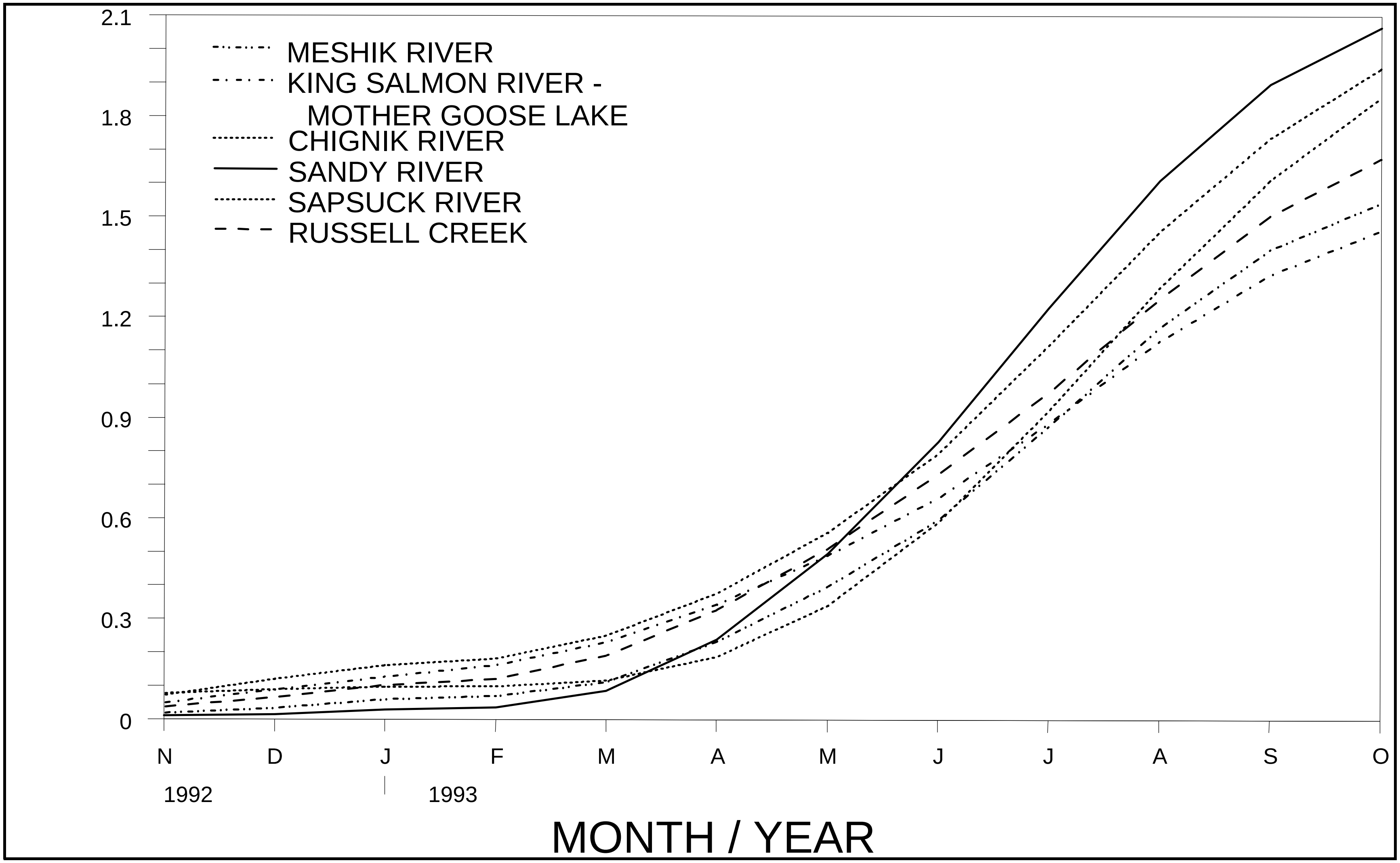

Figure 11.-Accumulated daily temperature units for all study drainages for the period October 1992-November 1993.

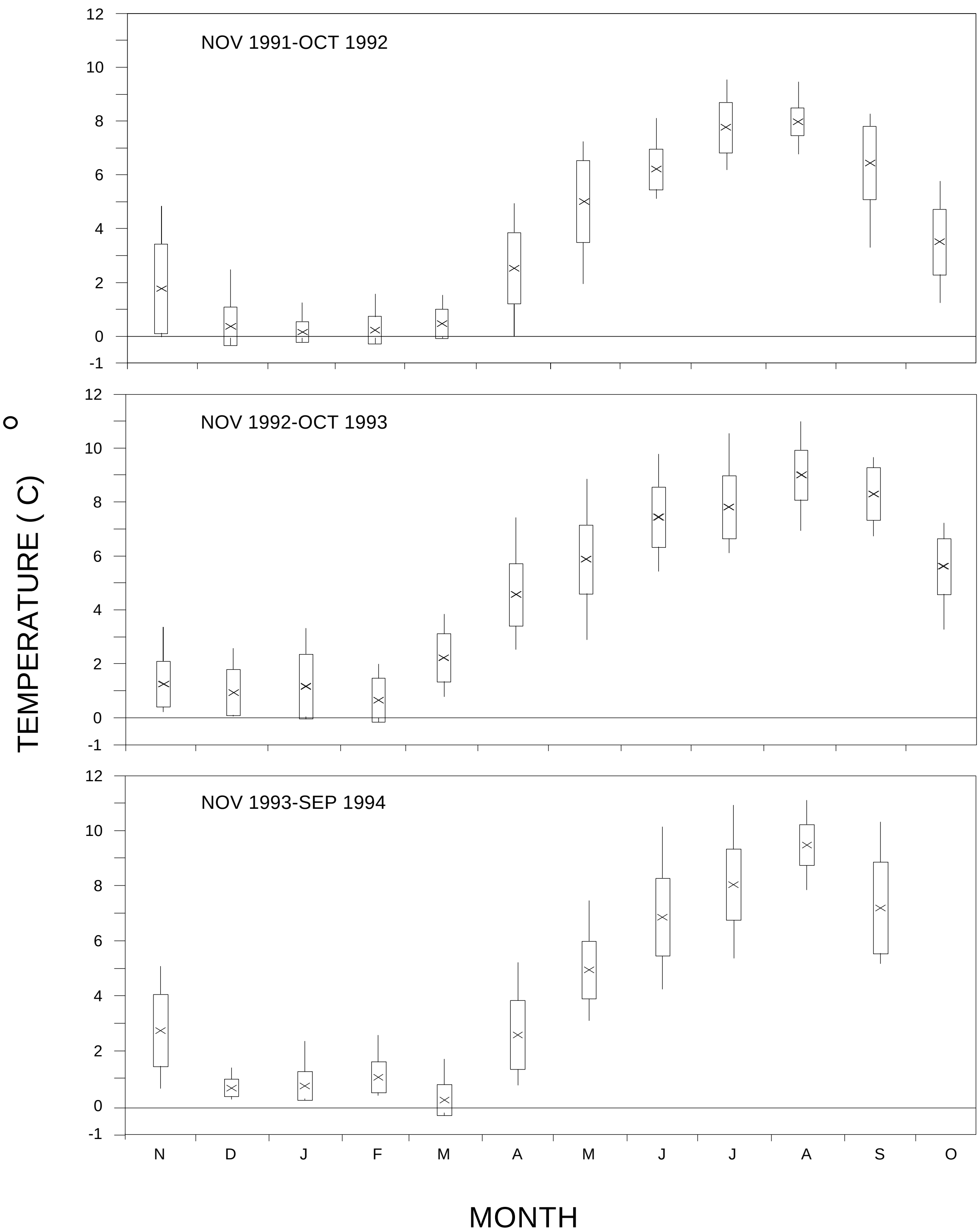

Figure 12.-Mean, standard deviation, and minimum and maximum monthly temperatures from Russell Creek.

spawning areas for steelhead trout in the Sapsuk River drainage but it is difficult to access.

During three years of searching and employing numerous sampling methods, steelhead trout were observed or captured only in the Sandy River and Russell Creek drainages. These drainages appear to be the only drainages on the Alaska Peninsula that have identifiable steelhead trout populations. The apparent absence of steelhead trout from systems reported to contain steelhead trout is puzzling. These systems are within the documented range of steelhead trout on the Alaska Peninsula and have water temperatures similar to Russell Creek. The apparent absence of steelhead trout from these systems could reflected low abundance due to limited or nonexistent spawning, rearing or overwintering habitat, or may reflect insufficient sampling effort in these access restricted locations.

Discrete habitat use patterns were observed for each life stage of steelhead trout during this study. Steelhead trout were found in Russell Creek drainage in all four years of the study. Adult steelhead trout were captured or observed both in the mainstem of Russell Creek and in Second Creek, while all redds observed were in the upper portion of Second Creek. All juvenile trout were captured in Second Creek except one which was captured in the mainstem. Additionally, juvenile trout were not evenly distributed throughout Second Creek. Though juvenile trout were found throughout the sample area on Second Creek, they were concentrated in the upper 1-2 km of the sample area.

The distribution pattern of steelhead trout was very different in Sandy River. Adult steelhead trout were captured only in the middle mainstem section of the Sandy River, while rainbow trout were captured throughout the mainstem. Though juvenile trout were distributed through out the mainstem and the lower portions of tributaries, 90% were captured in the middle mainstem area. Redds were observed only in the middle mainstem river.

The limited distribution of redds and juvenile trout in Sandy River and within the Russell Creek drainages indicates that steelhead may be highly selective in choosing spawning and rearing sites. This limited distribution emphasizes the necessity of thoroughly sampling each drainage.

At the initiation of this study the southern range of rainbow trout on the Alaska Peninsula was thought to be the King Salmon River-Egegik River drainage. There were no reported resident rainbow trout populations south of the King Salmon River-Egegik River drainage. Therefore, it was assumed any rainbow trout captured in the study area would be steelhead trout. However, scale analysis of the 1992 and 1993 Sandy River samples showed that both steelhead trout and rainbow trout were present in the drainage. Scale analysis showed that most of the samples lack the accelerated growth associated with the saltwater stage of steelhead trout. Based on a comparison of length at age, Sandy River samples were more similar to resident rainbow populations in King Salmon River-Egegik River drainage than the steelhead trout population in Russell Creek.

Abundance

Bank surveys provided a simple and reliable method of identifying and enumerating adult steelhead trout in the small, shallow Second Creek. However, the mainstem of Russell Creek was too wide and deep for reliable identification and enumeration of adult fish to be made with bank observations. Underwater observation provided a method of identifying and counting both adult and juvenile fish in the mainstem of Russell Creek. However, periods of poor visibility and some wide stretches of the creek proved that several observers may be required to provide reliable coverage of some larger systems.

The abundance estimates developed for juvenile trout in Second Creek should be considered as the minimum number present. Though abundance estimates using visual observations may often be precise, they are generally biased, and require a correction of diver counts (Hankin and Reeves 1988). The correction factor of diver counts in riffles was less than one and suggests divers misidentified juvenile Dolly Varden and other salmonids as steelhead trout or the various species were not equally vulnerable to removal seining. Unequal vulnerability biases the removal estimates and estimates of p_i, the proportion of fish that were steelhead trout. These biases apply to both riffles and glides. Effort should be increased in future studies so that the number of steelhead trout can be estimated directly by removal seining.

The low number of adult steelhead captured in Russell Creek and Sandy River may be a reflection of sampling timing or abundance. Due to weather, sampling could not be conducted before mid-May or later than October. Adult steelhead could have entered freshwater and returned to salt water before sampling could be conducted.

The relative absence of juvenile trout in the Sandy River drainage may reflect low abundance or dependance on habitat units that were not sampled. The tributaries of the Sandy River are small and may offer only marginal habitat compared to those of Russell Creek. Most of the juvenile trout in the Sandy River were captured in the mainstem where, due to depth, velocity and the inability to use blocknets, sampling was difficult. The difficulty in sampling the mainstem of the Sandy River may have given the impression of low numbers of juvenile trout being present.

Not all the juvenile trout capture data collected during this study were used for CPUE calculations. Data from the 1991 sample season were not included in CPUE calculations as sampling was focused on determining the presence of steelhead trout. Data from the 1994 sample season were not included in CPUE calculations as sampling focused on determining absolute abundance and capture effort included block nets and snorkeling. Adult steelhead trout were not included in CPUE calculations because sampling focused on juveniles and adult steelhead trout were often captured during directed sampling for other species. Variation in the size and morphology of Russell Creek and Sandy River drainages required that different sampling methods be used, resulting in high variability of effort and capture. Small sample sizes also prevented meaningful comparisons of CPUE between drainages.

Length, Weight, Age, and Sex Composition

In freshwater, steelhead trout juveniles generally grow to about 100 mm after their first winter and 150 mm by the end of their second winter (Burgner et al. 1992). In Alaska juvenile steelhead trout may spend 1-4 years in freshwater with most fish spending 3 years in freshwater (Sanders 1985). The steelhead trout population of Russell Creek and Sandy River exhibited a similar pattern though average length at age for juvenile trout in Russell Creek was smaller than the average length at age for juvenile trout from the Sandy River. Differences in average length at age may reflect a faster growth rate due to the warmer water in Sandy River than found in Russell Creek, stream productivity, genetics, or sample error. Differences in growth rates may also be due to the presence of rainbow trout juveniles in the Sandy River samples.

The spawning ages of steelhead trout in Alaska are highly variable (Sanders 1985). Steelhead may first spawn after only one winter at sea, however, most fish spawn for the first time after two or three winters at sea. In Russell Creek, 8 of the captured steelhead first spawned after spending two winters at sea, and 10 spawned for the first time after spending three winters at sea. The two Sandy River steelhead were spawning for the first time after having spent two winters at sea.

The outmigration of kelts in Alaska occurs anytime after spawning with the peak outmigration occurring usually before mid-July (Sanders 1985). The two male steelhead trout captured on July 26, 1992 in the Sandy River drainage appeared to have spawned in the spring, but had not yet returned to sea. All 11 adults captured in Russell Creek in May 1994 appeared to have recently spawned and were captured emigrating from Second Creek.

Steelhead trout samples from Russell Creek and Sandy River were of insufficient size to allow statistical comparisons of length at age, weight, and age distributions, and sex ratios with other populations. However, the data gave preliminary indications that Alaska Peninsula steelhead populations are similar to those found elsewhere in Alaska.

Water Temperature

Similar minimum temperatures were recorded within all drainages during winter months. These temperatures were often slightly below freezing but are within the 0.3 °C accuracy of the Ryan tempmentor model 1.1 thermographs. The extreme low of -2.0 °C recorded in the Meshik River in March, 1993 was probably caused by the thermograph coming in contact with air or an equipment malfunction. Maximum daily temperatures varied among drainages but were within expected ranges.

The mean daily temperatures from all drainages exhibited similar daily, seasonal, and annual temperature fluctuations. However, the mean daily temperatures from the Chignik River drainage were less variable than temperatures from the other drainages. This was probably due to the thermograph location in Chignik River drainage. Large lakes moderate diurnal temperature oscillations (Hynes 1970) and the thermograph in the Chignik River system was located approximately 1 km downstream from the Chignik Lake outlet. The proximity of the Chignik River thermograph to the lake moderated temperature changes and imparted a slight delay in general timing of seasonal temperature changes. Thermographs from the other drainages with large lakes, King Salmon River-Mother Goose Lake, Sapsuk River, and Sandy River, were placed a considerable distance from the lakes where the moderating effect of the lakes probably did not influence temperature.

Conclusions and Recommendations

The long-term benefit of the sampling program and integration of distribution, abundance, growth, and temperature data will not be fully realized until additional sampling is conducted in the future. Even though the weather and lack of logistic support make Alaska Peninsula a difficult area to work, we feel the project will be successful in meeting the long term goals of the Global Climate Change Study. It has taken several years to work out the sampling difficulties because of discontinuous distributions and small populations, but methods that sample large areas and relate distributions to habitat types seem to hold promise. Although all sampling methods may not work well in all drainages, we strongly encourage the use of one or two sampling techniques/gears that can be deployed in all drainages to facilitate direct comparisons among watersheds.

Future estimates of juvenile steelhead trout abundance in the Russell Creek drainage will best be achieved through a two stage sampling plan utilizing direct observation. The small amounts of gear and time needed to do direct observation with removal seining allowed coverage of a larger sample area that also helped minimize sampling error (Hankin and Reeves 1988). Direct observation methods should work well on small, clear water systems similar to Russell Creek but may be unsuited to turbid systems like the Sandy River. In systems like the Sandy River, it may be preferable to develop reliable CPUE data to monitor trends in juvenile abundance. Smolt traps may give reliable CPUE figures of emigrating smolts and would avoid most complications associated with the presence of resident rainbow trout juveniles. The aerial helicopter survey can be used to estimate spawning steelhead trout population sizes. However, its success is dependent on run timing, water depth, and clarity.

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